

## Optimization of the Building Energy Performance through Dynamic Modeling, Systems Simulation, Field Monitoring and Evaluation of Renewable Energy Applications

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### ABSTRACT:

The annual energy consumption in the residential and commercial sectors, in India is rising consistently at about 8% and the overall energy consumption in buildings has seen an increase from a low of 14% in the 1970s to nearly 33% in 2004/05. The electricity sector in India had an installed capacity of 254.049 GW as of end of September 2014. The research paper will deal with the modeling and optimization of the building energy performance by means of the application of the dynamic building simulation, the optimization of the energy systems and the verification of the energy consumptions and comfort conditions. An integrated tool is at an early stage of development to optimize the building energy performance to be expressed in terms of total energy use. The goal of the research paper is to optimize the building energy performance through the potential of the passive building technologies and the increase of efficiency of the building system.

**Keywords-** Evaluation, Modeling, Monitoring, Optimization of renewable energy use in buildings, Simulation.

### I. INTRODUCTION

The demand for energy in developing countries is becoming alarming, whereas the means of electricity production remains limited. Due to climatic change high temperature and humidity, significantly increases the use of air conditioners to attain better thermal comfort. Depletion of fossil fuels and increase in fuel cost leads to an electricity shortage. The energy crisis made an effort in reducing the overall energy consumption in building sector.

Energy is a vital input for social and economic development. As a result of the generalization of agricultural, industrial and domestic activities the demand for energy has increased remarkably, especially in emergent countries. Despite the obvious advantages of renewable energy, it presents important drawbacks, such as the discontinuity of generation, as most renewable energy resources depend on the climate, which is why their use requires complex design, planning and control optimization methods.

Fortunately, the continuous advances in computer hardware and software are allowing researchers to deal with these optimization problems using computational resources, as can be seen in the large number of optimization methods that have been applied to the renewable and sustainable energy field.

The residential sector in India consumes 37% of energy reflecting the importance of the sector in the national energy scenario. Electricity consumption is mainly influenced by seasonal variation in residential building. Most of the energy consumed for cooling,

electrical appliances and water heating, these depend mainly on the ambient temperature. Around of 50% of annual energy is consumed for air conditioning with an average electric energy ratio of 100 kWh/m<sup>2</sup> of floor space.

Energy resource efficiency in new constructions can be effected by adopting an integrated approach to building design. The primary steps in this approach are:

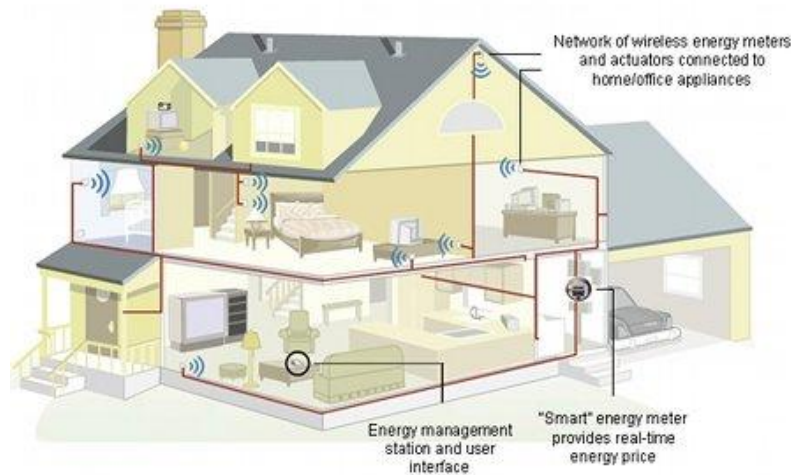
- Incorporate solar passive techniques in a building design to minimize load.
- Use renewable energy systems (geothermal heat pump, solar energy, wind energy).

The meaning of energy modeling, is using computer based tools to simulate the energy use of a building throughout an entire year of operation. In many cases, architects and building owners are inexperienced with energy modeling and don't know how to harness this powerful tool to inform the design and decision making process. Properly used, energy modeling can help optimize the building design and allow the design team to prioritize investment in the strategies that will have the greatest effect buildings energy use. Our most stringent energy codes and prescriptive guidelines today get us no more than 30% savings over common practice. What we need are 50%, 60% and greater savings, and we need early modeling to get there.

Building construction and operations can have extensive direct and indirect impacts on the environment, society, and economy, which are commonly referred to as the 3 P'S (people, planet,

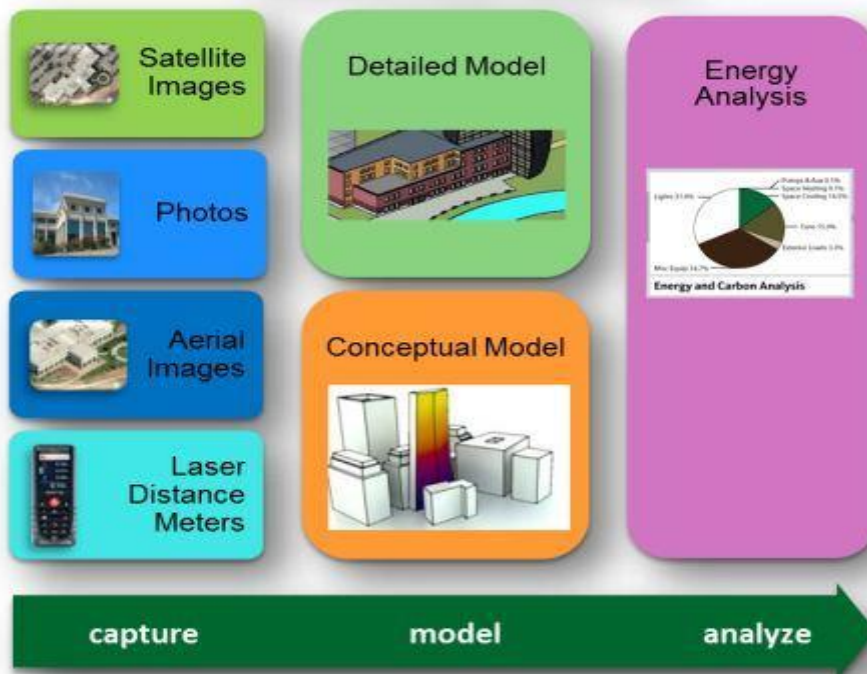
pocketbook). In India residential energy consumption represents 39% of final energy consumed and slightly less (37%) in terms of primary energy consumption. However, energy consumption in the residential sector in India is still largely dominated by the use of

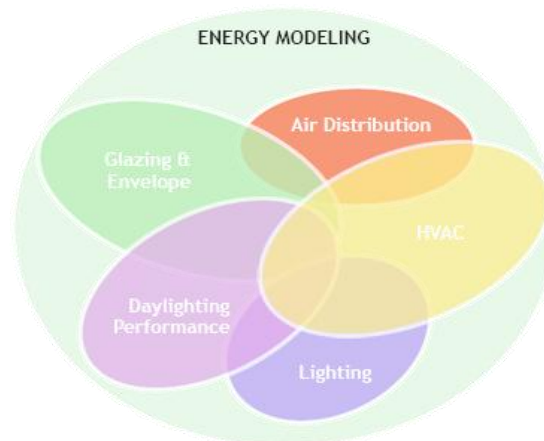
firewood. When biomass energy use is excluded, residential energy use represents only 12% of total final energy use and 19% of total primary energy use. India is one of the largest growing economies in the world with economic growth rate of 8.9%.



Standard economic approach to energy modeling based on learning from existing models and simulations software, such as, MESSAGE, MARKAL, WEM, etc. in view of recent development of technologies and techniques.

### Rapid Energy Modeling





Building simulation is commonly divided into two categories : Load Design, and Energy Analysis. Load design is used to determine :

- Air conditioning loads (the amount of cooling / heating energy needed by a space / system / building).
- Volumetric air flow requirements (the amount of air needed to cool / heat a space).
- Equipment capacities (since equipment may condition multiple spaces).
- Supply temperatures.
- Hydronic plant capacities (worst case simultaneous load).
- Similarities and differences between equipment options for heating and cooling a space.

Energy analysis is used to :

- Predict the monthly energy consumption and bills.
- Predict the annual energy cost.
- Annual carbon dioxide emissions.
- Compare and contrast different efficiency options.
- Determine life cycle pay back on various options.

Energy monitoring is an energy efficiency technique based on the standard management axiom stating that “you can not manage what you can not measure”. Monitoring information of energy use, in order to establish a basis for energy management and explain deviations from an established pattern. Its primary goal is to maintain said pattern, by providing all the necessary data on energy consumption, as well as certain driving factors, as identified during preliminary investigation.

Goals of energy monitoring are :

- Identify and explain excessive energy use.
- Detect instances when consumption is unexpectedly higher or lower than would usually have been the case.

- Visualize energy consumption trends (daily, weekly, seasonal, operational).
- Determine future energy use and costs when planning changes in business.
- Diagnose specific areas of wasted energy.
- Observe how changes to relevant driving factors impact energy efficiency.
- Develop performance targets for energy management programs.
- Manage energy consumption, rather than accept it as a fixed cost.

Benefits of energy monitoring are : Throughout the numerous monitoring projects implemented since the 1980's, a certain number of benefits have proved to be recurrent –

- Energy cost savings.
- Improved budgeting.
- Waste avoidance.

An energy evaluation is an inspection, survey and analysis of energy flows for energy conservation in a building, process or system to reduce the amount of energy input into the system without negatively affecting the output. In commercial and industrial real estate, an energy evaluation is the first step in identifying opportunities to reduce energy expense and carbon footprints.

The research activity will deal with the modeling and optimization of the building energy performance by means of the application of the dynamic building simulation, the optimization of the energy systems and the verification of the energy consumptions and comfort conditions.

## II. METHODOLOGY

The procedure involves five major steps, viz. i) A set of passive building technologies that minimize the net energy needs for heating and cooling, ii) A set of packaged energy systems that exploit renewable sources with the maximum effectiveness, iii) The

analysis of the trade-off between the energy needs minimization (energy modesty), energy efficiency and the renewable sources exploitation, iv) A tool to minimize the total energy use in buildings - software includes SIMUL8, energy evaluator online tool, business program eligibility tool, large general service, EMS (energy management software), energy planning tool, and v) The verification of the previous findings by means of field measurements for the tuning of the decision models and for the creation of benchmarks.

SIMUL8 : Benefits of SIMUL8 –

- Mimic the operation of actual system.
- Cost benefit analysis.
- Apply statistical methods to capture the unpredictable variations and randomness of life.
- Evaluate operational decisions before actual implementation.

Benefits of energy evaluator tool –

- Reduce energy costs and raise awareness of energy usage.
- Help to review progress over time.
- Help one gain a greater understanding of how to achieve energy efficiency and how to lock in energy savings for the future.

Business program eligibility tool that are used by business users to perform various business functions. These business applications are used to increase productivity, and to perform business functions accurately. Types of business program eligibility tools –

- Enterprise application software.
- Resource management.
- Digital dashboards.
- Reporting software.
- Procurement software.
- Business performance management.
- Document management.
- Employee scheduling software.

An energy management system is a system of computer aided tools used by operators of electric utility grids to monitor, control and optimize the performance of the generation and / or transmission system.

Energy planning tool is used to help one to produce reports and plans in compliance.

The five steps are briefly discussed below.

Employing passive building technologies: Employing passive building technologies: Passive building technologies do not require mechanical heating or cooling. Homes that are passively designed take advantage of natural energy flows to maintain thermal comfort.

Passive building technologies in our homes:

- Significantly improves comfort.
- Reduces or eliminates heating and cooling bills.
- Reduces greenhouse gas emissions from heating,

cooling, mechanical ventilation and lighting.

Effective renewable energy solution package:

- a) Use space heaters in the winter: Rather than heating our entire house to keep warm in the winter, consider the use of portable space heaters in only the occupied rooms of our home. For example, if we go from watching television in the den to our bedroom, we can simply move the space heater from the den to our bedroom. This can have a huge impact on the environment and our wallet, by preventing the waste of energy to warm rooms that are unoccupied.
- b) Use ceiling fans as much as possible: Most homes are equipped with ceiling fans, and using them can save a great deal in energy costs. For those homes that do not have ceiling fans installed, the cost of purchase and installation can easily and quickly be recouped by our energy savings.

In the winter, run the ceiling fan on low speed in a clockwise direction. This creates an updraft that flows warm air down. In the summer, run the ceiling fan counter-clockwise. This blows air down-wards and cools the room, without having to rely on energy-sucking air conditioning.

- c) Turn off lights we aren't using: I hope this lesson is in pre-school, because turning the lights off in unoccupied rooms is probably the easiest and cheapest change we can make.
- d) Install low-flow fixtures: Low flow shower and faucet fixtures can save a bundle by reducing the amount of energy used to heat our water as well as the cost of water itself.
- e) Dry clothes on a clothesline or rack: We don't have to give up our dryer for good- even foregoing every once in a while can save a good deal of money and energy, with the added bonus of our clothes smelling like the great outdoors.
- f) Install a programmable thermostat- Programmable thermostats automatically adjust the temperature of our living space depending on a pre-determined schedule. Most of us, for example, don't need the thermostat set to 70 degrees during summer days when we are at the work. A well-programmed thermostat can save us up to 20% on our heating and cooling bill.
- g) Use cold water to wash clothes- Heating up water for the hot cycle uses more energy, and with the advent of more efficient washing machines and cold water detergents, typically our clothes will get just as clean using cold water.
- h) Unplug energy vampires: Things like our computer, television, video game console, cell phone charger and kitchen electrics use almost as much power when they are plugged in and sitting idle and unused as when in use. To save a good deal on our electricity bill, focus on unplugging

these items when they are not in use.

- i) Switch to CFLs: Switching from incandescent light to compact fluorescent lighting carries an upfront cost, as the bulbs are much more expensive than the incandescent variety. Start buying CFLs now as our current bulbs burn out and break, and reap the benefits.
- j) Lower the temperature on hot water heater: Chances are, we rarely crank our shower temperature all the way to the red stopper, which means we won't notice the difference if we set the temperature on our hot water heater from an average of 130 degrees to 120 degrees. This simple gesture can save our 3-5% on energy costs annually.

Comparative economics: Economic analysis is specifically concerned with the related issues of supplies and demands and the interrelated issues of production, consumption and distribution of goods and services.

Comparative economics of conventional and alternative energy systems:

- Oil, coal, natural gas, nuclear and large scale hydro.
- Hydro, biomass, wind, geothermal, geo-pressured, photovoltaic energy.
- Synthesis gas, bio-fuels, batteries and fuel cells.

Software for optimizing energy use:

- a) Building IQ: Building IQ provides a unique Software-as-a-Service ( SaaS ) solution to optimize energy use in commercial buildings. Its predictive Energy Optimization uses advanced algorithms to automatically fine tune and control HVAC systems resulting in savings while maintaining or improving comfort. Small changes in temperature and pressure result in customers savings of 10-25% in HVAC energy costs. Customers can also earn significant improvements in their LEED, NABERS and other sustainability measures.
- b) BE opt: The BE opt ( Building Energy Optimization ) software provides capabilities to evaluate residential building designs and identify

cost-optimal efficiency packages at various levels of whole-house energy savings along the path to zero net energy. BE opt can be used to analyze both new construction and existing home retrofits, through evaluation of single building designs, parametric sweeps, and cost-based optimizations.

BE opt provides detailed simulation-based analysis based on specific house characteristics, such as size, architecture, occupancy, vintage, location and utility rates. Discrete envelope and equipment options, reflecting realistic construction materials and practices, are evaluated.

The sequential search optimization technique used by BE opt:

- Finds minimum cost building designs at different target energy savings levels.
- Identifies multiple near optimal designs along the path, allowing for equivalent solutions based on builder or contractor preference.

Validation: Energy validation means validate bills against the agreed contract or tariff rates to ensure that no overpayment occurs.

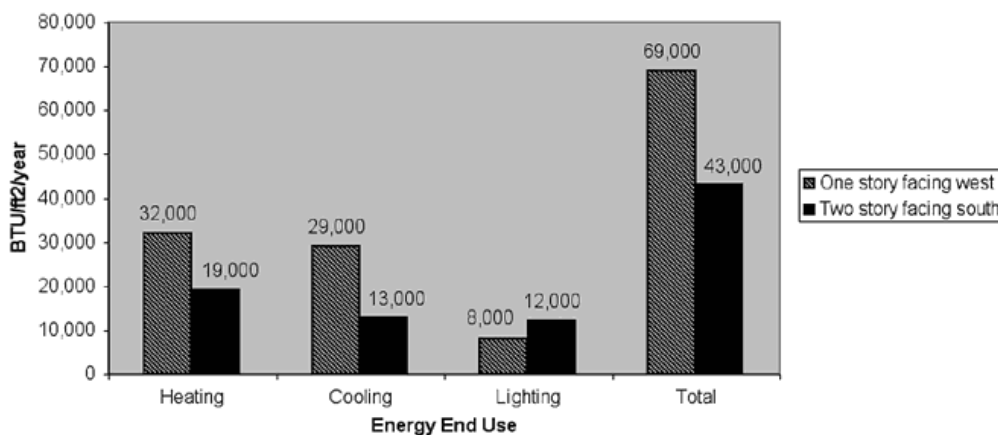
Some of the variables we have to check are:

- Consumption units match the load profile data by time band.
- Meter readings follow on correctly.
- Unit rates are correctly applied in accordance with the agreed contract.
- Distribution losses are correctly applied.
- Transmission losses are correctly applied if applicable.
- Supply capacity charges have been correctly applied.
- Identify poor power factors and abnormally high or low load factors.

### III. RESULTS AND DISCUSSION

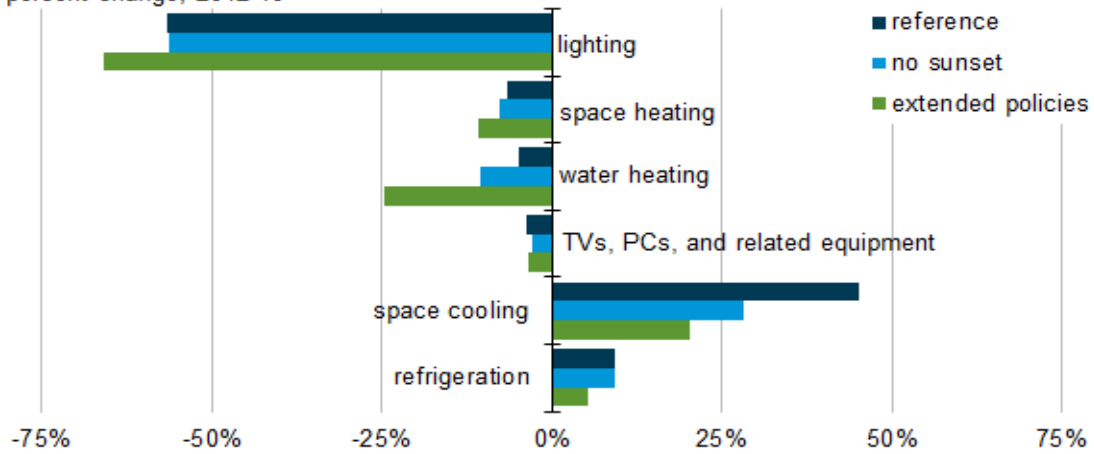
Results obtained are presented in four categories, as following:

- i) Modeling and optimization of the building energy performance.

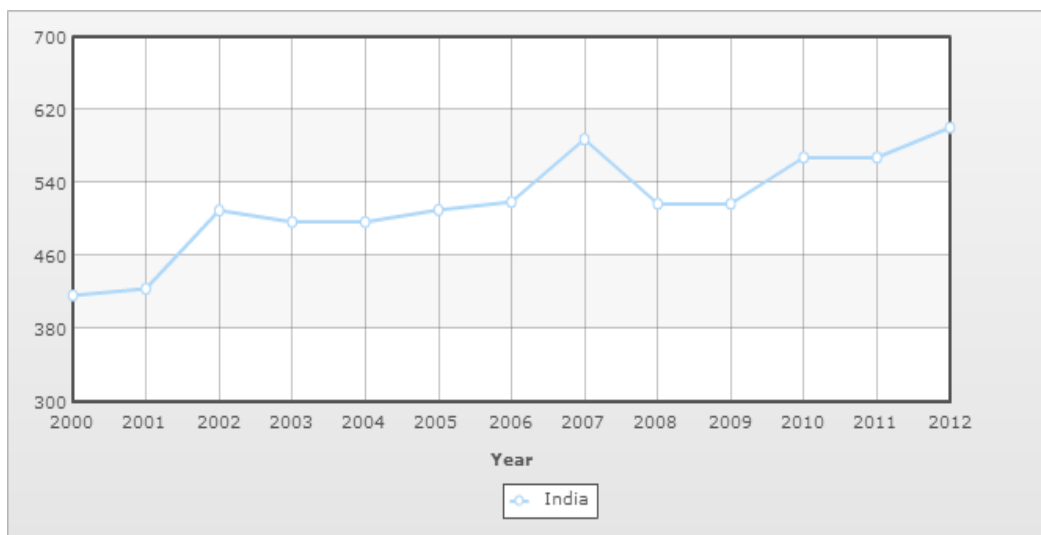
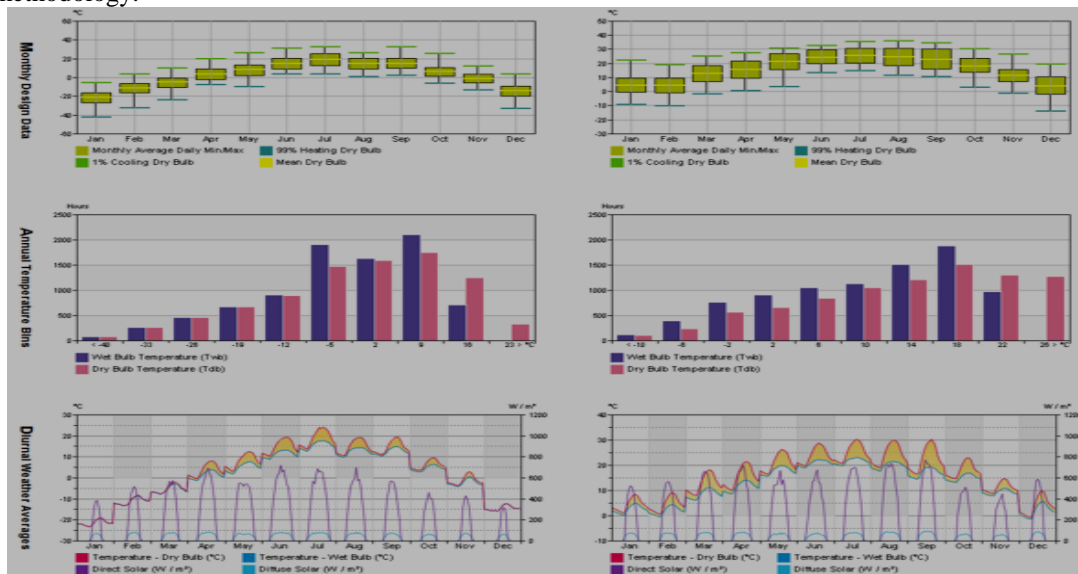


ii) Verification of the energy consumptions and comfort conditions.

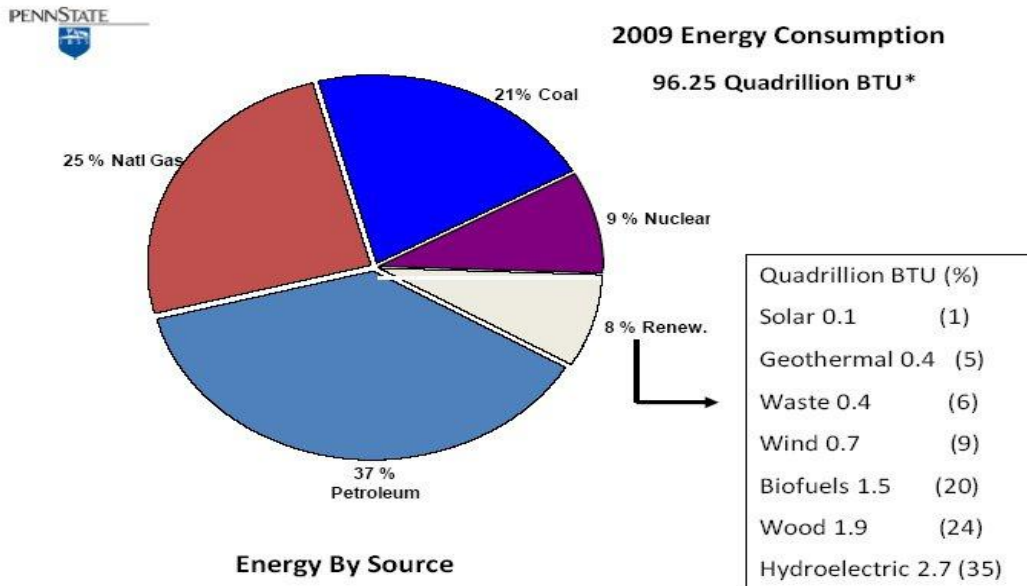
**Change in residential delivered energy consumption for selected end uses**  
 percent change, 2012-40



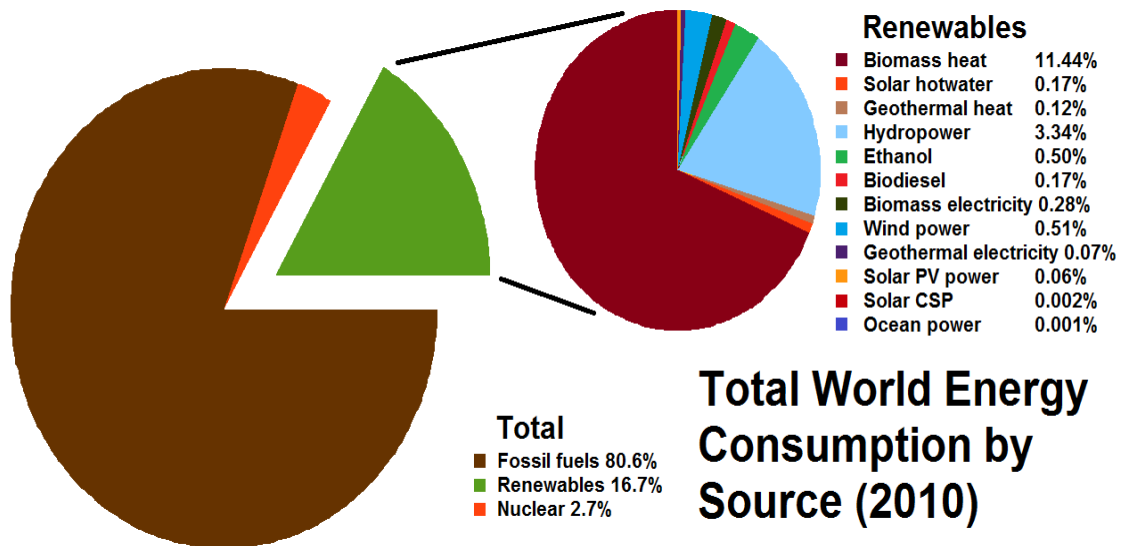
iii) Simulations results showing increase in the efficiency of the building system through the energy hub methodology.



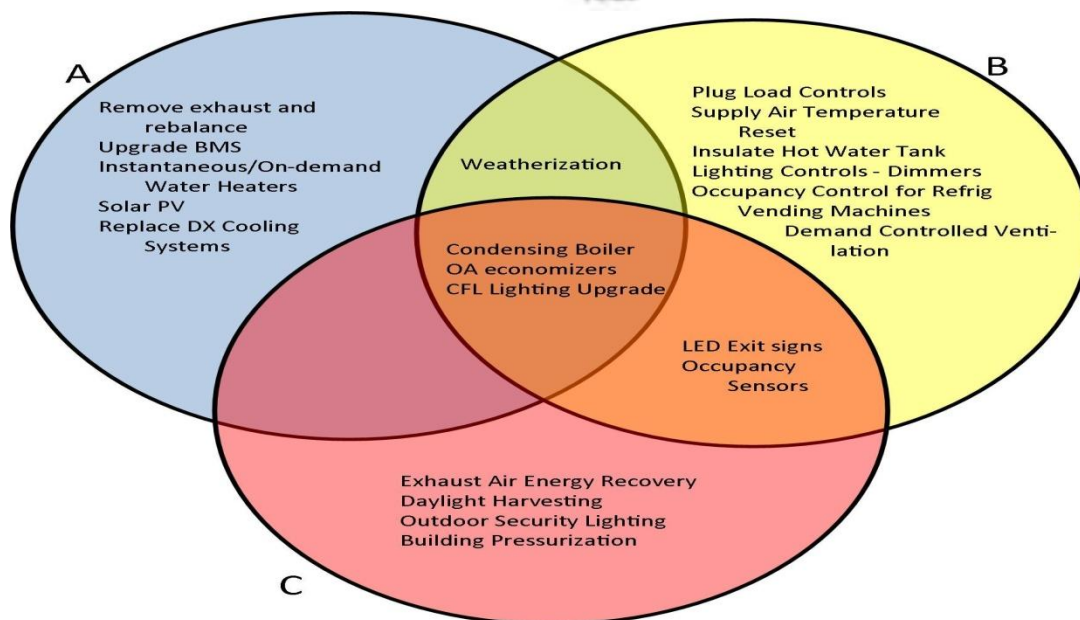
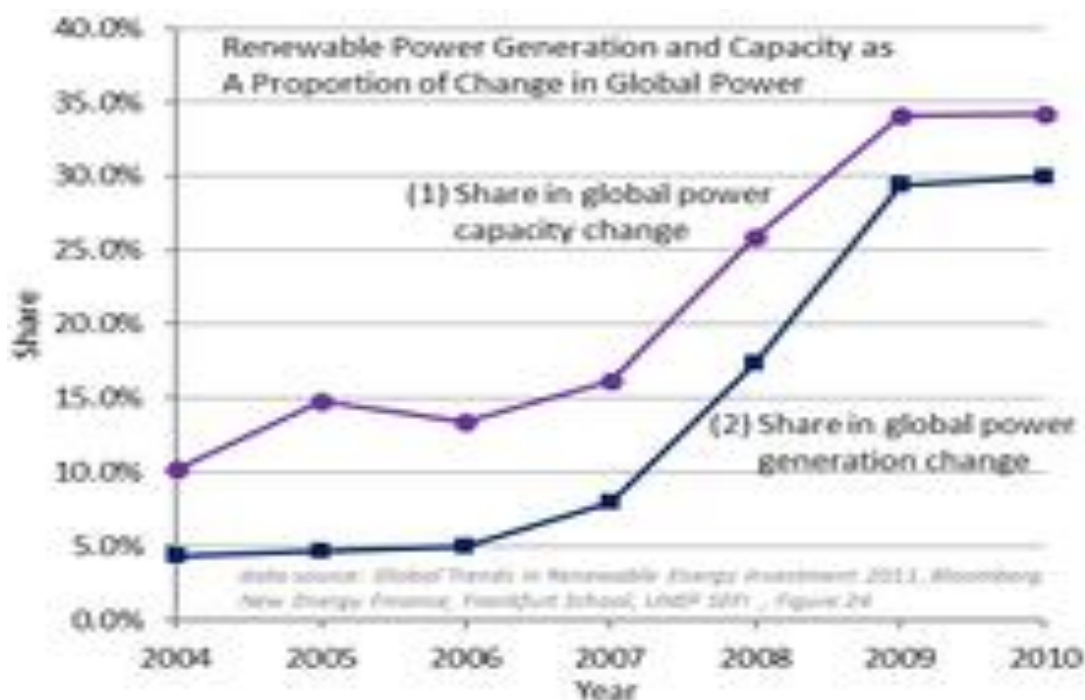
iv) Employing judiciously the application of locally available renewable energy resources.



\* Ref. DOE/EIA-0384 (2009) /Aug 2010







#### IV. CONCLUSION

An integrated tool is at an early stage of development to optimize the building energy performance to be expressed in terms of total energy use. The goal of the research activity is to optimize the building energy performance through the potential of the passive building technologies and the increase of efficiency of the building system.

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